Response to comments on the 2015 report titled *Deschutes River, Capitol Lake, and Budd Inlet Total Maximum Daily Load Study: Supplemental Modeling Scenarios*

1. Comment: *Water quality violations in Capitol Lake itself were vastly overestimated.*

Response: Low dissolved oxygen levels measured in Budd inlet resulted in a 303(d) impaired water listing. Low oxygen in the inlet is due to complex interactions between the physics, chemistry and biology of the system, of which Capitol Lake is a part of. The 2015 report contains a set of modeling scenarios developed by the Deschutes Advisory Group to evaluate potential actions that may be considered to improve the water quality in Budd Inlet. Though the 2015 supplemental report contains a discussion about the dissolved oxygen standard applicable to the lake, it does not present estimates of water quality violations in Capitol Lake itself—but rather focuses on violations in Budd Inlet.

In 2012, Ecology published predictions of violations in the lake itself based on different loading scenarios. The model runs were calibrated and verified using, among others, data from an extensive field monitoring campaign. The model successfully captured the system's long-term trends. Please refer to Appendix H of publication 12-03-008 which contains calibration and verification plots for temperature, dissolved oxygen, nitrogen, phosphorus and chlorophyll as well as organic carbon and biological oxygen demand.

2. Comment: *The calculations of Total Organic Carbon (from plant growth) entering the Sound from the Lake or Estuary scenarios overstate the amount of TOC in the Lake case and underestimate it in the Estuary case.*

Response: Ecology compared the modeled concentration of total organic carbon (TOC) at the location of the outflow from Capitol Lake with and without the dam in place. The TOC concentration, with a seasonal peak as high as 5 mg/L compared with 2 mg/L without the dam, is significantly higher due to the dam. Organic carbon increases due to the growth of freshwater plants in Capitol Lake. The increased production of organic carbon, combined with longer residence times for decomposition, leads to significantly greater depletion of dissolved oxygen in Budd Inlet due to the presence of the dam.

Generally good agreement is found when one compares modeled lake parameters indicative of algal carbon, such as particulate organic carbon (POC), to measurements *(see calibration plots for POC for lake-inlet, mid-lake and lake-outlet stations in Appendix H. Capitol Lake Water Quality Model Calibration and Verification in Roberts et al. 2012 report)*. In addition, good agreement between observed and modeled nitrate, ammonia and organic nitrogen concentrations are also presented in the above reference. Global carbon to nitrogen ratios are pretty consistent in the environment according to the Redfield ratio. A good calibration with nitrogen is reflective of appropriate simulation of carbon in the system.

3. Comment: *An inappropriate technique was used to calculate East Bay waters residence times.*

Response: There are two major scientific methods of estimating residence times:

1) The first one is based on hydrodynamics and is simply the volume (V) of the waterbody divided by the net outflow (Q) from the water body or V/Q. This method assumes that the waterbody behaves as a completely stirred tank reactor and is not realistic. This approach underestimates residence times as it

does not consider the variation in bathymetry, shape and orientation of the waterbody. It only accounts for advective transport not including dispersion.

2) The second method is based on introducing a conservative tracer such as a dye in the waterbody and then study the concentration of dye as a function of time. The time to reach a concentration of 1/e (37%) is defined as the residence time or e-folding time. This method is deemed superior as it accounts for both advective and dispersive transport mechanisms. This is the method used for East Bay waters.

The following references in the published scientific literature contain further information on this topic:

Monsen, N.E., J.E. Cloern, L.V. Lucas, and S.G. Monismith, 2002. A comment on the use of flushing time, residence time, and age as transport time scales. *Limnology and Oceanography* **47**(5):1545-153.

Khangaonkar T. and T. Wang. 2013. Potential alteration of fjordal circulation due to a large floating structure—Numerical Investigation with application to Hood Canal basin in Puget Sound. Applied Ocean Research. Volume 39, January 2013, Pages 146–157

4. Comment: *The authors mistakenly assume that Capital Lake's ecology is phosphorus limited and base several pages of irrelevant discussion and calculation on that assumption.*

Response: Ratios of nitrogen to phosphorus indicate whether primary productivity is limited by one or both nutrients. The traditional Redfield ratio was developed for marine algae, but is often applied to freshwater systems as well. Mass ratios of nitrogen to phosphorus greater than 7.2:1 indicate that nitrogen is available in abundance, and phosphorus is limiting. Ecology measured nutrient levels at Capitol Lake as reported by Roberts et al. (2012) in *Deschutes River, Capitol Lake, and Budd Inlet TMDL: WQ Improvement Report*. Ratios based on mean nitrogen to phosphorus concentrations measured at Capitol Lake generally exceed 20:1, indicating phosphorus limitation (Roberts et al, 2012 p. 79-80). Capitol Lake nutrient concentrations reflect seasonal influences. The lake is phosphorus limited fall through spring. During the summer months, primary productivity reduces both dissolved inorganic nitrogen (DIN) and orthophosphate to very low levels, to the point that nitrogen limited primary productivity in summer 2003. (Roberts et. al, 2012 p. 84)

5. Comment: *The Budd Inlet model produces many demonstrably wrong answers when compared with observed data; yet the authors consider every dissolved oxygen calculation accurate to within 0.2 mg/L.*

Response: In the early 1990s, Ecology recognized that in some cases anthropogenic sources could cause a de-minimis change in dissolved oxygen, which Ecology defined as 0.2 mg/L. Ecology recognized that this amount would usually be estimated through modeling (e.g., the difference between model runs with and without anthropogenic loading sources). In applying this criterion, Ecology understood that model uncertainty would likely be at least as large as measurement error, and likely be greater than the 0.2 mg/L allowable deficit, but that allowing the 0.2 mg/L deficit would provide some relief to permittees, such that in many cases discharges would not have to be removed from impaired waterbodies.

The ability of the Budd Inlet model to predict observed data, or model skill, was evaluated using two statistical measurements: the square root of the average of the squared differences between predicted and observed values, also called the root mean squared error (RMSE), and the average of the differences between the predicted and observed values (mean bias). Model skill statistics presented in Roberts et al. (2012), indicate expected temporal and spatial variations. The model cannot be expected to have a lower error than the measurement error, or perform with the same level of skill (such as within 0.2 mg/L) at all locations or times. Measurement error constitutes the smallest difference in dissolved oxygen concentrations that can be resolved quantitatively in the field. The RMSE is comparable to similar model calibration studies in South Puget Sound.

In 2015 , the model was used to calculate *differences* in dissolved oxygen between various anthropogenic loading scenarios compared with the natural condition to determine whether the predicted differences exceeded the water quality standard. The model is considered to be suitable for the main purpose of the project which was to predict the response of bottom dissolved oxygen concentrations in inner Budd Inlet to variations in nutrient loading and concentration.

6. Comment: *Answers derived from the authors' method of finding water quality standards "violations" are not subject to independent confirmation or refutation by scientist elsewhere.*

Response: Ecology followed a repeatable approach that can be reproduced by independent reviewers, can be reviewed by all stakeholders, and meets the requirements of the Clean Water Act and water quality standards.

7. Comment: *The authors' hypothesis of how organic carbon created by plants in the Lake enter and affect Budd Inlet is not ecologically realistic, and contrary to their claim, is not testable by the Budd Inlet model.*

Response: The model did a reasonable job of reproducing observed data describing the transformation of inorganic dissolved nutrients into organic matter in Capitol Lake. The mechanism of uptake of inorganic nutrients and production of organic material by plants is ecologically realistic and commonly applied in numerical modeling of water quality (e.g. as described in textbooks such as *Surface Water-Quality Modeling*, Steven Chapra, McGraw Hill 1987).

8. Comment: *A Figure showing water quality violations in the hypothesized pre-modern estuary is formatted in a way that makes it impossible to judge the extent of the violations; proper formatting shows that violations are as widespread in the natural water as they are today with Capitol Lake present.*

Dissolved Oxygen (DO) Depletion in mg/L

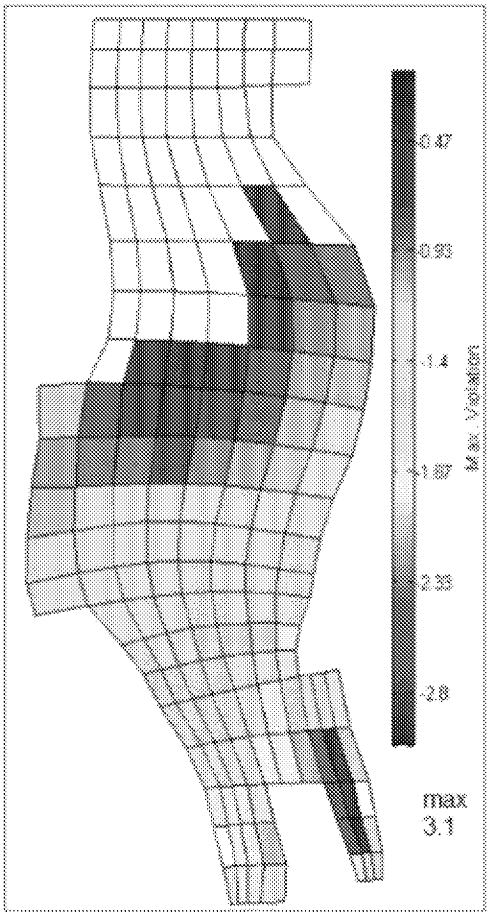

Figure 8. DO depletion caused by all anthropogenic impacts including Capitol Lake dam.

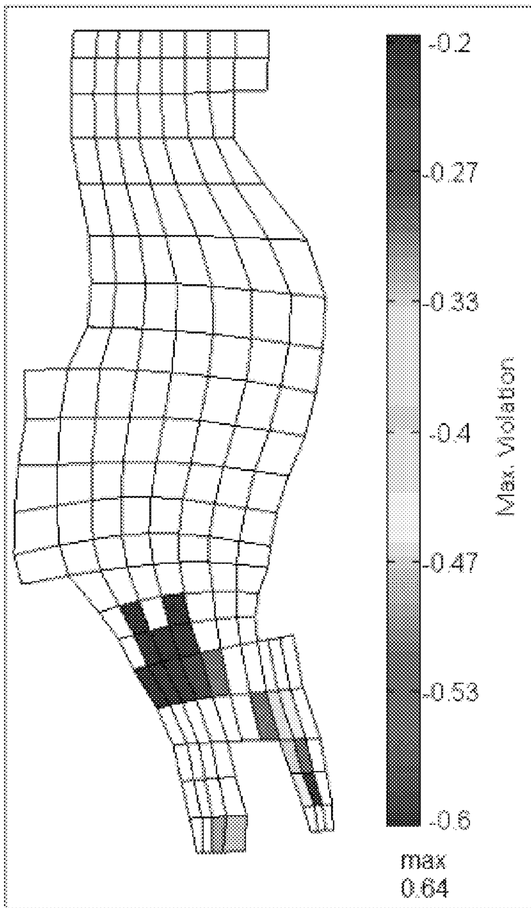

Figure 17. DO depletion caused by anthropogenic nutrient loading but without Capitol Lake dam.

Response: Comparison of figures 8 and 17, found on page 33 and 40 of the report, and shown above, show the impact in Budd Inlet on the dissolved oxygen depletion that would occur with no Capital Lake dam. Natural conditions do not constitute a violation of the water quality standard.

9. Comment: *There is no figure showing violations in modern water if the dam were not present—a critical omission making it impossible to see whether the 'estuary scenario" would be better or worse than the "lake scenario".*

Response: Please refer to Figure 17, on page 40, which shows the dissolved oxygen depletion caused by the combined effect of all anthropogenic nutrient loads but without Capital Lake dam. The maximum dissolved oxygen violation shown is 0.64 mg/L. Figure 9, on page 34, shows the geographic extent of dissolved oxygen depletion caused solely by Capital Lake Dam. The maximum dissolved oxygen violation shown is 1.84 mg/L.

10. Comment: *The authors avoided simulating the effect on the Lake/Inlet interaction that would result from a program of harvesting plants, an option that might improve Inlet water quality.*

Response: The September 2011 and February 2012 advisory group meetings identified the scenarios related to Capitol Lake to be analyzed. The scenario for harvesting lake plants was either prioritized lower by the committee or could not be evaluated quantitatively. Harvesting lake plants (macrophytes) would result in removal of very large masses of plant material, which would need to occur several times during the growing season. Reducing macrophytes in 2004 via herbicide application may have contributed to the massive algal blooms that followed. For more information, see page 69, Ecology publication number 15-03-002.

11. Comment: *The authors avoided simulating the Lake's effect on the inlet if nutrient nitrogen levels in the Deschutes River were reduced, an option that might improve Inlet water quality.*

Response: The September 2011 and February 2012 advisory group meetings identified the scenarios related to Capitol Lake to be analyzed. Several scenarios involve nutrient reductions. For instance, note that Figure 33, on page 56, contains results for a model run with Capital Lake dam in place and without human sources. Figure 33 shows that the impact of all anthropogenic nitrogen sources, including those within the Deschutes watershed, in terms of maximum oxygen depletion at East Bay is only a small fraction of the maximum oxygen depletion due to the dam alone. A nonlinear relationship exists between nutrient load reduction and oxygen benefit. Management scenarios must consider controlling multiple sources to achieve water quality standards.

12. Comment: *Figures included from other sources, said to bolster author's claim, actually show the opposite; beneficial removal by Capitol Lake of nutrient nitrogen from Deschutes River water.*

Response: Ecology compared the predicted concentrations of dissolved inorganic nitrogen at the location of the lake outflow both with and without the dam in place. The report also presents measured concentrations from three different field campaigns that show variability between the total nitrogen in Capitol Lake and the incoming Deschutes River water. While the growth of plants in the lake converts nearly all of the inorganic nitrogen into organic nitrogen in plant cells and detritus, plants concurrently also convert inorganic carbon to organic carbon. It is this production of organic carbon that is largely responsible for depletion of dissolved oxygen in Budd Inlet.

Overall, the system can be described as follows: Capitol Lake receives nutrient inputs from the Deschutes River and Percival Creek. These nutrient inputs within the lake environment fuel growth of various plant species, including algae blooms. On an annual basis, a significant portion of the total nitrogen entering Capitol Lake is released into Budd Inlet as organic nitrogen, with most of the remainder likely becoming entrained in the sediments. Capitol Lake produces substantially more oxygen-demanding organic carbon than would occur in a natural estuary. Organic carbon is released into Budd Inlet. As the excess organic carbon decays, oxygen is used up. Furthermore, Capitol Lake dam alters circulation in southern Budd Inlet, increasing the residence time of East Bay water. Nutrient and organic carbon enriched water remains in East Bay for longer periods creating conditions for algae growth, organic matter decomposition and lower oxygen concentrations than would occur without the dam in place.